Intech 204-IJS

METHOD FOR TRACKING THE LOCATION OF MOBILE UNITS

BACKGROUND OF THE INVENTION

The present invention relates to a method for tracking the location of mobile units.

There is currently a great need for the tracking of the location of mobile units, particularly wireless transmitters or transceivers that are worn or carried on a person, so as to keep track of that person's location. The mobile units also can have sensors which sense voltage, temperature, vital signs, etc., and thus it is also important for the mobile unit to be able to transmit this information under adverse conditions.

Many problems arise from the use of such units, particularly where many units are present in a given area, and there is a need to accurately identify each individual unit, as well as to accurately identify the location of the unit.

SUMMARY OF THE INVENTION

The main object of the present invention is to provide a method for tracking the location of mobile units which is achieved by calculating the coordinates of the location of a mobile unit with a unique identification.

Another object of the present invention is to calculate the coordinates of the location of each mobile unit by measuring the phase difference of signals arriving at antenna elements of a phase array antenna at the base unit from a mobile unit.

Preferably, measuring of the phase difference is performed in the base unit, whereas the step of calculating the coordinates is performed in a main unit connected to the base unit and comprising a programmable computer, for example, an Intel Pentium II based personal computer having a Windows 98 operating system, or any kind of programmable computer system.

Each mobile unit may have one or more sensors, and the signal that is received from the mobile unit includes information or an information signal, may include an output from the sensor and a mobile unit address (identification number). The information from the sensor is processed preferably by the main unit.

The wireless transmitter or transceiver used in the mobile unit is preferably a radio frequency transmitter, and more preferably, a radio frequency transceiver.

Another object of the present invention is to improve the tracking method by a method for calibrating a system for tracking the location of mobile units.

Still another object of the present invention is to improve the accuracy of the location tracking by providing two or more base units disposed at a predetermined position apart from each other and measuring the azimuth of the signal received from each mobile unit at the antenna elements of the base units.

In accordance with the present invention, the base unit or phase difference measurement and communication unit (PDMCU)

has the phase array antenna for receiving signals from a plurality of mobile wireless transmitter units or portable wireless interfaces (PWI) and at least one reference wireless transmitter or beacon is disposed at a fixed location. The beacon is at a known location with regard to the base unit and has a unique identifying address which identifies it as a beacon or reference unit.

A signal including the address is received from the beacon at the base unit via the phase array antenna. The phase difference between the signal arriving at the antenna elements from the beacon is measured and the coordinates of the location of the beacon are then calculated. Future calculations can then be corrected by the difference between the calculated coordinates of the beacon and the actual location of the beacon. Thus, when calculations are performed thereafter for mobile units, similar corrections can be performed to the calculated coordinates in order to find the actual location of those mobile units.

To further increase accuracy of the location detection, a plurality of base units can be used. In this case, the locations of the base units are known and each base unit will measure the azimuth direction of the mobile unit.

These and other objects and advantages of the present invention are achieved in accordance with the present invention disclosed in detail hereinafter with reference to the attached

drawings, wherein

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of the system for carrying out the method of the present invention;

Fig. 2A is a drawing showing the method for calculating the polar coordinates;

Fig. 2B is a drawing showing the method for calculating the X,Y coordinates;

Fig. 3 is a drawing showing the calculation of the calibration corrections;

Fig. 4 is a block diagram of the mobile units of Fig. 1;

Fig. 5 is a block diagram of the beacon of Fig. 1;

Fig. 6 is a block diagram of the base units of Fig. 1;

Fig. 7 is a block diagram of the main unit of Fig. 1: and

Fig. 8 is a drawing of a phase difference measurement circuit in the base unit.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to Fig. 1, a system is shown for carrying out the method of the present invention for the detection of the location and identification of mobile units 40 by the use of a

phase array antenna 30.

The system may have a single base unit 20, but preferably has a plurality of addressable base units each with antenna elements in a phase antenna array 30. The base unit receives a signal from a mobile unit or beacon 50 at each antenna element. There will be a resulting phase difference and the function of the base unit is to measure the phase difference and communicate it to main unit 10. The function of the main unit is to process information from the base units and mobile units and communicate the information. The base units 20 are connected to the main unit or computation and communication module 10 in a hard-wired manner as shown in Fig. 1 or through a wireless connection. Moreover, while the base units 20 are shown to be connected in parallel, they can also be connected via a network to the main unit 10. While a single main unit is shown, it is understood that the system can include a plurality of main units each having base units connected thereto. In the various system configurations that have been described, each base unit has a unique address that is sent to the main unit with all transmissions and this unique address also permits each base unit to be addressable by the main unit.

The main unit 10 is preferably a programmed microcomputer, such as an Intel Pentium II based computer having Windows 98 operating system plus a network controller module which serves as an interface between the base units and the computer.

The base unit comprises a circuitry for measuring the phase difference of the signals arriving from the mobile units 40 or from a beacon 50, as well as having circuitry for information

data detection from each mobile unit 40 or beacon 50. The base units 20 also have the ability to communicate with the main unit 10, either by means for of a driver along a hard-wire line or by means of a radio transceiver for wireless communication.

The system also includes the aforementioned mobile or portable wireless interface units 40 of which any number can be used, as long as each has a unique address which it is capable of communicating to the base units 20. The mobile units include a transmitter, preferably a radio frequency transceiver, as well as any number of a set of sensors that can be used to make telemetry readings. The outputs of the sensors are communicated via the transmitters to base units and thereafter to the main unit so as to be processed therein.

The main unit 10, which is preferably a computation and communication module, as noted above, comprises a programmed personal computer and utilizes software for the portable wireless interface unit location calculation and database management for storing the sensor readings, along with the locations for each mobile unit 40.

The system also includes beacons 50 which are fixed location wireless transmitters or transceivers, whose location relative to the phase array antenna of the base units 20 are known to the main unit 10. The system can use one or more beacons 50, depending upon the environment, that is, if the signals therefrom would be blocked from the various phase array

antennas 30.

In accordance with the invention, once there is a measurement in the base unit 20 of the phase difference of the signal received from a mobile unit 40, the main unit 10 will calculate the coordinates of the location and process the data from the sensors.

The method according to the present invention combines the location and identification of any mobile unit by using multiple phase array antennas and transfers the collected information to an information management system in the main unit which can also collect and process the information from sensors attached to the mobile units 40.

Referring now to Fig. 2A, the calculation of the polar coordinates R, α of a tracked object is explained using the phase array antenna in a radio frequency identification type system.

As shown in Fig. 2A, O is the tracked object with a transmitter or transceiver and A, B and C are antenna elements. It has been found that the location can be determined by using just two antenna elements when at least two base units are used.

The base unit 20 measures the phase difference of points A,C relative to point B ($\Delta\Phi_A$, $\Delta\Phi_C$) electronically at points A and C respectively.

In accordance with the invention, the antenna elements can be positioned in such a way that, for example, $\lambda/2$ or any needed distance for a particular application. For example

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$$AB = BC = \frac{\lambda}{2} \quad \text{or}$$
$$AB = BC = \lambda$$

or any other desired value.

As a result

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$$\Delta\Phi_A = \frac{2\pi AD}{\lambda}$$
$$\Delta\Phi_C = \frac{2\pi EC}{\lambda}$$

From these equations, if Φ_A and Φ_C are known, then the angles θ_1 and θ_2 can be calculated, as we can see from the following example.

If we assume that

$$AB = BC = \lambda$$
$$\lambda << OB$$
$$\lambda << OA$$
$$\lambda << OC$$
$$\Delta\Phi_A = 90^\circ = \frac{\pi}{2}$$

then

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$$AD = \frac{\Phi_A \lambda}{2\pi} = \frac{\lambda}{4}$$
$$\cos\theta_1 = \frac{AD}{AB} = \frac{\lambda}{4\lambda} = \frac{1}{4}$$
$$\theta_1 = 75.5^\circ$$

Once angles θ_1 and θ_2 are known, then

OF=h

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FC=x

AF= 2λ-x

$$h = x\tan\theta_2$$
$$h = (2\lambda - x)\tan\theta_1$$
$$x\tan\theta_2 = 2\lambda\tan\theta_1 - x\tan\theta_1$$
$$x(\tan\theta_1 + \tan\theta_2) = 2\lambda\tan\theta_1$$
$$x = \frac{2\lambda\tan\theta_1}{\tan\theta_1 + \tan\theta_2}$$
$$h = x\tan\theta_2$$
$$h = \frac{2\lambda\tan\theta_1\tan\theta_2}{\tan\theta_1 + \tan\theta_2}$$

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Then the radius vector R can be determined as follows

$$R = OB = \sqrt{(\lambda - x)^2 + h^2}$$
$$\tan\alpha = \frac{h}{\lambda - x}$$

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The polar coordinates R, α define the exact location of a tracked object at any given moment in time.

Multiple base units can measure the azimuth of the same mobile unit from different locations and transmit this information to the main unit. In this case, the main unit can provide better accuracy of the location coordinates for the mobile units.

The coordinate calculations for an object position using two phase array antennas, each with two antenna elements when the distance between the elements is λ/2 is now explained with the help of Fig. 2B.

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The following are known: $B_1(x_0, O)$, $A_2(O, y_0)$, θ_1, θ_2. The problem is to find $O_1(x_1, y_1)$.

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$$\frac{y_1}{\frac{\lambda}{2} - (x_1 - x_0)} = \tan\theta_1$$

$$y_1 = \left(\frac{\lambda}{2} - x_1 + x_0\right)\tan\theta_1$$

$$y_1 = \left(\frac{\lambda}{2} + x_0\right)\tan\theta_1 - x_1\tan\theta_1$$

$$\frac{x_1}{y_0 - y_1} = \tan\theta_2$$

$$x_1 = (y_0 - y_1)\tan\theta_2$$

$$x_1 = y_0\tan\theta_2 - y_1\tan\theta_2$$

$$y_1 = \left(\frac{\lambda}{2} + x_0\right)\tan\theta_1 - y_0\tan\theta_1\tan\theta_2 + y_1\tan\theta_1\tan\theta_2$$

$$y_1 = \frac{\tan\theta_1\left(\frac{\lambda}{2} + x_0 - y_0\tan\theta_2\right)}{1 - \tan\theta_1\tan\theta_2}$$

$$x_1 = \tan\theta_2\left[y_0 - \frac{\tan\theta_1\left(\frac{\lambda}{2} + x_0 - y_0\tan\theta_2\right)}{1 - \tan\theta_1\tan\theta_2}\right]$$

The last two equations represent the coordinates of the tracked object O_1 by using two phase array antennas and are expressed through given quantities x_0, y_0, θ_1, θ_2.

Fig. 3 shows how the beacon 50 can be used for the calibration of the radio frequency identification system.

One or more beacons are positioned in a constant position, so that the exact locations, that is, their

coordinates, are defined by the needed application and are known. In this example the polar coordinates are used, but it is understood that it is equally applicable to other coordinates.

O_1 and O_2 and O_3 are the actual positions of the beacon, whereas O', O" and O"' are points from which the electronic signals were calculated as being received.

A number of electronic measurements are taken for the position of the beacon. They are then averaged, and then one calculates the average of ΔO_1, ΔO_2 and ΔO_3 and the final average ΔO will be used for calibration and accounted for in $\Delta\Phi_A$ and $\Delta\Phi_B$.

BEACON AT	R_{BEACON}	α_{BEACON}	SIGNAL FROM	DISPLACEMENT VECTOR
O_1	R_1	α_1	O'	$\vec{O}'\vec{O}_1 = \Delta O_1$
O_2	R_2	α_2	O"	$\vec{O}''\vec{O}_2 = \Delta O_2$
O_3	R_3	α_3	O"'	$\vec{O}'''\vec{O}_3 = \Delta O_3$

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Fig. 4 shows the details of the mobile unit 40. The unit includes a microprocessor 401 which receives inputs from one or more sensors 405 and which has a hard-wired address 402 which is unique and which is received by the microprocessor 401.

The microprocessor 401 controls transceiver 404 which communicates via antenna 403 with the base units 20. The microprocessor 401 controls the transceiver so as to transmit the sensor information, along with the address information, and to

receive polling information from the base units 20.

The details of the beacon 50 are shown in Fig. 5. The beacon 50 includes a microprocessor 501 which receives, as an input, a unique address from 502 which identifies the beacon as a reference source, as opposed to a portable wireless interface unit 40. The microprocessor 501 controls the transceiver 504 to transmit a reference signal, along with the address, via antenna 503. The beacon can also have a sensor connected to it.

The transceivers 404 and 504 can be an RFM TR3001 transceiver, a Linx TXN-315-LC transmitter of comparable device from Motorola, Airnet, Intellon or Proxim. Microprocessors 401 and 501 can be conventional Intel, Motorola microprocessors or others.

The sensors 405 can sense telemetry information such as current, flow, leakage, motion, pressure, smoke, temperature, vibration, vital signs, and voltage.

Fig. 6 shows the details of the base unit 20. This unit is controlled by a microprocessor 201 which receives, for example, the phase difference signals $\Delta\Phi_A$ and $\Delta\Phi_C$ from phase difference measurement circuit 204. The signals, along with the address data, are processed by the microprocessor which sends the address data to the address detector 202 to determine the source of the signal. The base unit also has a unique address which is stored in 205 and which is sent along with data to the main unit. The microprocessor 201 communicates with the main unit 10 via the

I/O 203. The I/O 203 can be either a UART for transmitting asynchronous data to the main unit 10, either in parallel, as shown in Fig. 1, or via a network, or it can be a transceiver transmitting the information including the address to and from the main unit via wireless communication.

Fig. 7 illustrates the main unit 10. The main unit 10, as noted above, can be a programmed microcomputer, including a microprocessor 101 and an I/O 103 which is managing the wired or wireless network with I/O 203 of the base unit 20. The main unit 10 also includes a database 102 in which the information from the sensors is stored, along with the location and identification of each mobile unit. The main unit has an address detector 104 which determines which base unit it is receiving data from. Microprocessors 101 and 201 can be conventional Intel, Motorola microprocessors or others.

Fig. 8 illustrates the phase difference measurement circuit 204 that is used to measure each phase difference. In the circuit shown, two antenna elements A and B are used and the phase difference $\Delta\phi$ is measured and sent to microprocessor 201. The circuit has a voltage controlled oscillator and modulator 208 which is a surface acoustic wave or phase lock loop based. Data from the main unit 10 used to poll the mobile unit or beacon is input and passed through amplifier 213 to switch 209 which connects the signal to antenna elements A and B for transmission to the mobile units and/or beacons.

When a signal is received at the antenna elements A and B, the switch 209 is set in the receive position and the signals are passed through low noise amplifiers 214 to mixers 210 where the signals are mixed with an output from local oscillator 206, which is a surface acoustic wave or phase lock loop based oscillator by Temic or Atmel. The output of the mixers is received by intermediate frequency receivers 207 which are for example NE605 by Philips. The data demodulated from the signals are combined at 212 to improve gain and constitute the data out signal sent to the microprocessor 201. The directional signals are fed to phase difference detector 211 which is a 74HCT9046. The output is the phase difference sent to microprocessor 201.

It is understood that the embodiments described hereinabove are merely illustrative and are not intended to limit the scope of the invention. It is realized that various changes, alterations, rearrangements and modifications can be made by those skilled in the art without substantially departing from the spirit and scope of the present invention.